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Bd. 1876

The Gift of
Mrs. & Miss Clarke,
of Newton,
18 December, 1848.

THE

MANURES

MOST ADVANTAGEOUSLY APPLICABLE TO THE

VARIOUS SORTS OF SOILS,

AND

THE CAUSES

OF

THEIR BENEFICIAL EFFECT

IN EACH PARTICULAR INSTANCE.

——Idoneus patriæ, ſit utilis agris.
Juv. Sat. 14.

By RICHARD KIRWAN, Esq. F.R.S. & M.R.I.A.
Author of the Elements of Mineralogy, &c.

FIFTH EDITION.

London,

PRINTED FOR VERNOR AND HOOD, POULTRY,

By W. Blackader, 10, Took's Court, Chancery Lane.

1802.

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WHAT ARE THE MANURES MOST ADVANTAGEOUSLY APPLICABLE TO THE VARIOUS SORTS OF SOILS;

AND,

WHAT ARE THE CAUSES OF THEIR BENEFICIAL EFFECT IN EACH PARTICULAR INSTANCE.

——IDONEUS PATRIÆ, SIT UTILIS AGRIS.
Juven. Sat. 14.

AGRICULTURE is the art of making the earth produce the largeſt crop of uſeful vegetables at the ſmalleſt expence. It has often been remarked, that amidſt the various improvements which moſt of the practical arts have derived from the progreſs lately made in natural philoſophy and chemiſtry, none have fallen to the ſhare of agriculture, but that it remains nearly in the ſame ſtate in which it

exiſted two thouſand years ago. I am far from allowing the truth of this obſervation, taken in its totality; to refute it, we need only compare the writings of Cato, Columella, or Pliny, with many modern Tracts, or ſtill better, with the modern practice of our beſt farmers. It muſt be granted, however, that vague and fortuitous experience has contributed much more to the preſent flouriſhing ſtate of this art than any general principles deduced from our late acquired knowledge, either of the proceſs of vegetation, or of the nature of ſoils; but the ſkill thus fortuitouſly acquired is neceſſarily partial, and generally local; the very terms employed by the perſons who moſt eminently poſſeſs it, are generally of a vague and uncertain ſignification. Thus Mr. Young, to whoſe labours the world is more indebted for the diffuſion of agricultural knowledge than to any writer who has as yet appeared, remarks, That in ſome parts of England, where huſbandry is ſucceſsfully practiſed, any looſe clay is called marl *; in others, marl is called chalk †; and in others, clay is called loam ‡. Philoſophic re-

* Firſt Eaſtern Tour, 178. † 2 Bath Mem. 192, 220.
‡ 2 Bath Mem. 137.

ſearches

ſearches have been made, not yet ſufficiently noticed; much information may be derived from Monſieur Du Hamel, and much more from the well-directed experiments of Mr. Tillet *. Immenſe ſtrides have been made in this career, by the illuſtrious Bergman; Dr. Prieſtly's experiments have thrown a new light on this, as well as on every other object of natural philoſophy. Mr. Layoiſier's new theory explains many circumſtances, before inexplicable; diſcoveries of great importance have been made by Mr. Senebier and Dr. Ingenhouz: even Mr. Young has not always confined his attention to the mere practical part, but ſometimes happily extended it to objects of a more general and ſpeculative nature; but the fulleſt light, perhaps, has been thrown on this ſubject by the late diſcoveries of Mr. Haſſenfraz †.

If the exact connexion of effects, with their cauſes, has not been ſo fully and ſo extenſively traced in this as in other ſubjects, we muſt attribute it to the peculiar difficulties of the inveſtigation. In other ſubjects, expoſed to the

* Mem. Par. 1772. † Annales Chymiques, Vol. 13, 14.

joint operation of many cauſes, the effect of each, ſingly and excluſively taken, may be particularly examined; the experimenter may work in his laboratory with the object always in his view; but the ſecret proceſſes of vegetation take place in the dark, expoſed to the various and indeterminable influences of the atmoſphere, and require at leaſt half a year for their completion. Hence the difficulty of determining on what peculiar circumſtance ſucceſs or failure depends; the diverſified experience of many years can alone afford a rational foundation for ſolid ſpecific concluſions. It cannot therefore be expected that new, deciſive, and direct experiments ſhould be laid before the Academy within the time preſcribed for anſwering this queſtion. The reſolution of the firſt part muſt be deduced from a ſtatement of facts long eſtabliſhed by multiplied experience; and that of the ſecond, by the application of more general principles to the explanation of thoſe facts.—But before we proceed to either branch of this queſtion, the diſtinctions and denominations both of ſoils and manures muſt be exactly ſettled and accurately defined.

CHAP.

CHAP. I.

OF SOILS AND MANURES.

SECTION I.

Of Soils.

LAND, conſidered as the baſis of vegetation, is called *ſoil.*

Soils conſiſt of different combinations of two or more of the four primitive earths, namely, the calcareous (which I ſometimes call mild calx) magneſia, argill, and the ſilicious. For a more accurate deſcription of theſe I muſt refer to books of mineralogy; and ſhall only remark, that by calcareous earths are meant chalk, and all ſtones that burn to lime. They are eaſily diſtinguiſhed by their property of efferveſcing with acids.

Magneſia is never found alone; its diſtinguiſhing character conſiſts in affording a bitter

ſalt, generally called Epſom Salt, when combined with the vitriolic acid.

Argill is that part of clay to which this owes its property of feeling ſoft and unctuous, and of hardening in fire; it is difficultly ſoluble in acids, and ſcarce ever effervesces with them. When combined with the vitriolic acid, it forms alum.

Silicious Earth is often found in a ſtony form, ſuch as flint or quartz; and ſtill more frequently in that of a very fine ſand, ſuch as that whereof glaſs is made. It does not effervesce, nor is it ſoluble in any of the common acids.

To theſe we may add Iron, in that imperfect ſtate in which it exiſts when reduced to ruſt, and commonly called Calx of Iron.

The ſoils moſt frequently met with, and which deſerve a diſtinct conſideration, are clay, chalk, ſand, and gravel, clayey loam, chalky loam, ſandy loam, gravelly loam, ferruginous loam, boggy ſoil, and heathy ſoil or mountain, as it is often called.

Clay is of various colours; for we meet with white, grey, browniſh red, browniſh black, yellow or bluiſh clays; it feels ſmooth, and

ſomewhat

ſomewhat unctuous: if moiſt, it adheres to the fingers, and if ſufficiently ſo, it becomes tough and ductile. If dry, it adheres more or leſs to the tongue: if thrown into water, it gradually diffuſes itſelf through it, and ſlowly ſeparates from it. It does not uſually effervefce with acids, unleſs a ſtrong heat be applied, or that it contains a few calcareous particles, or magneſia. If heated, it hardens and burns to a brick.

It conſiſts of argill and fine ſand, uſually of the ſilicious kind, in various proportions, and more or leſs ferruginous. The argill forms generally from 20 to 75 per cwt. of the whole maſs; the ſand and calx of iron the remainder. Theſe are perfectly ſeparable by boiling in ſtrong vitriolic acid.

Chalk, if not very impure, is of a white colour, moderate conſiſtence, and duſty ſurface, ſtains the fingers, adheres ſlightly to the tongue, does not harden when heated, but, on the contrary, in a ſtrong heat burns to lime, and loſes about four-tenths of its weight. It effervefces with acids, and diſſolves almoſt entirely therein. I ſhall alſo add, that this ſolution is not diſ-

turbed by cauſtic volatile alkali, as this circumſtance diſtinguiſhes it from magneſia,—it promotes putrefaction.

Sand. By this is meant ſmall looſe grains of great hardneſs, not cohering with water, nor ſoftened by it. It is generally of the filicious kind, and therefore inſoluble in acids.

Gravel differs from ſand chiefly in ſize: however ſtones of a calcareous nature, when ſmall and rounded, are often comprehended under that denomination.

Loam denotes any ſoil moderately coheſive: that is, leſs ſo than clay, and more ſo than looſe chalk. By the Author of the Body of Agriculture, it is ſaid to be a clay mixed with ſand. Doctor Hill defines it an earth compoſed of diſſimilar particles, hard, ſtiff, denſe, harſh, and rough to the touch, not eaſily ductile while moiſt, readily diffuſible in water, and compoſed of ſand and a tough viſcid clay. The definition I have given ſeems moſt ſuited to the different ſpecies I ſhall now enumerate.

Clayey Loam denotes a compound ſoil, moderately coheſive, in which the argillaceous ingredient predominates. Its coherence is then greater

greater than that of any other loam, but leſs than that of pure clay. The other ingredient is a *coarſe* ſand, with or without a ſmall mixture of the calcareous ingredient. It is this which farmers generally call *ſtrong*, *ſtiff*, *cold*, and *heavy* loam, in proportion as the clay abounds in it.

Chalky Loam. This term indicates a loam formed of clay, coarſe ſand, and chalk; in which, however, the calcareous ingredient or chalk much predominates. It is leſs coheſive than clayey loams.

Sandy Loam denotes a loam in which ſand predominates: it is leſs coherent than either the abovementioned. Sand, partly coarſe and partly fine, forms from 80 to 90 per cent. of this compound.

Gravely Loam differs from the laſt only in containing a larger mixture of coarſe ſand, or pebbles. This and the two laſt are generally called by farmers, *light* or *hungry* ſoils; particularly when they have but little depth.

Ferruginous Loam, or *Till.* This is generally of a dark brown, or reddiſh colour, and much harder than any of the preceding: it conſiſts

fists of clay and calces of iron, more or less intimately mixed. It may be distinguished not only by its colour, but also by its superior weight: it sometimes effervesces with acids, and sometimes not; when it does, much of the irony part may be separated, by pouring it, when well dried, into spirit of salt; from which the iron may afterwards be separated by alkalis or chalk.

———Akin to this are certain *vitriolic soils*, which when steeped in water, impart to it the power of reddening syrup of violets. These are generally of a blue colour, but redden when heated.

Boggy Soil, or *Bogs*, consist chiefly of ligneous roots of decayed vegetables mixed with earth, mostly argillaceous, and sand, and a coaly substance derived from decayed vegetables. Of bogs there are two sorts: the black, which contain a larger proportion of clay and of roots more perfectly decayed, with mineral oil. In the red the roots seem less perfectly decayed, and to form the principal part.

Heathy Soil is that which is naturally productive of heath.

Section II.

Of Manures.

Manure denotes any ſubſtance or operation by which a ſoil is improved. To improve a ſoil is to render it capable of producing corn, legumens, and the moſt uſeful graſſes.

The ſubſtances principally uſed as manures, are chalk, lime, clay, ſand, marl, gypſum, aſhes, ſtable-dung, mucks, farm-yard dung, pounded bones, ſea-weeds, ſweepings of ditches, old ditches. Other manures or top-dreſſings, as they are employed chiefly to promote the growth of vegetables, and not merely with a view of improving the ſoil, I omit.

The operations uſed to improve ſoils, are fallows, draining, paring and burning.

Of chalk, clays, and ſand, we have already treated.

Lime is a ſubſtance whoſe external characters and mode of production are well known. It differs from chalk and powdered limeſtone chiefly by the abſence of fixed air, which is expelled

expelled from theſe during their calcination. This air it greedily reabſorbs from the atmoſphere, and all other bodies with which it comes in contact, and which can furniſh it; but it cannot unite with the air unleſs it is previouſly moiſtened. 100 parts quick-lime abſorb about 28 of water. It is ſoluble in about 700 parts of this fluid. To regain its full portion of air from the atmoſphere, it requires a year or more, if not purpoſely ſpread out: it reſiſts putrefaction; but with the aſſiſtance of moiſture, it reſolves organic ſubſtances into a mucus.

Marl is of three ſorts; calcareous, argillaceous, and ſilicious or ſandy. All are mixtures of mild calx (*i. e.* chalk) with clay, in ſuch a manner as to fall to pieces by expoſure to the atmoſphere more or leſs readily.

Calcareous Marl is that which is moſt commonly underſtood by the term *Marl*, without addition. It is generally of a yellowiſh white, or yellowiſh grey colour; rarely brown or lead coloured. It is ſeldom found on the ſurface of land, but commonly a few feet under it, and on the ſides of hills, or rivers that flow through calcareous countries, or under turf in bogs.

Frequently

Frequently of a looſe texture, ſometimes moderately coherent; rarely of a ſtony hardneſs, and hence called *ſtone-marl.* Sometimes of a compact, ſometimes of a lamellar texture; often ſo thin as to be called *paper-marl.* It often abounds with ſhells, and then is called *ſhell-marl*; which is looked upon as the beſt ſort. When in powder, it feels dry between the fingers; put in water, it quickly falls to pieces or powder, and does not form a viſcid maſs. It chips and moulders by expoſure to the air and moiſture, ſooner or later, according to its hardneſs and the proportion of its ingredients: if heated, it will not form a brick, but rather lime. It effervesces with all acids. It conſiſts of from 33 to 80 per cent. of mild calx, and from 66 to 20 per cent. of clay.

To find its compoſition, pour a few ounces of weak, but pure ſpirit of nitre or common ſalt into a Florence flaſk; place them in a ſcale and let them be balanced; then reduce a few ounces of dry marl into powder, and let this powder be carefully and gradually thrown into the flaſk, until after repeated agitation no effervesçence is any longer perceived; let the remainder

mainder of the powdered marl be then weighed, by which the quantity projected will be known; let the balance be then reſtored; the difference of weight between the quantity projected and that requiſite to reſtore the balance will diſcover the weight of air loſt during effervescence; if the loſs amounts to 13 per cwt. of the quantity of marl projected, or from 13 to 32 per cwt. the marl eſſayed is calcareous marl. This experiment is deciſive, when we are aſſured by the external characters above mentioned, that the ſubſtance employed is marl of any kind; otherwiſe ſome ſorts of the ſparry iron-ore may be miſtaken for marl. The experiments to diſcover the argillaceous ingredient (being too difficult for farmers) I omit. The reſidue left after ſolution, being well waſhed, will, when duly heated, generally harden into a brick.

Argillaceous Marl contains from 68 to 80 per cwt. of clay, and conſequently from 32 to 20 per cwt. of aerated calx. Its colour is grey or brown, or reddiſh brown, or yellowiſh or bluiſh grey. It feels more unctuous than the former, and adheres to the tongue; its hardneſs generally much greater. In water it falls

to

to pieces more ſlowly, and often into ſquare pieces: it alſo more ſlowly moulders by expoſure to the air and moiſture, if of a looſe conſiſtence: it hardens when heated, and forms an imperfect brick. It effervesces with ſpirit of nitre or common ſalt, but frequently refuſes to do ſo with vinegar. When dried and projected into ſpirit of nitre in a Florence flaſk, with the attentions above-mentioned, it is found to loſe from 8 to 10 per cwt. of its weight. The undiſſolved part, well waſhed, will when duly heated harden into a brick.

Silicious, or *Sandy Marls*, are thoſe whoſe clayey part contains an exceſs of ſand: for, if treated with acids in the manner above-mentioned, the reſiduum, or clayey part, will be found to contain above 75 cwt. of ſand; conſequently chalk and ſand are the predominant ingredients.

The colour of this marl is browniſh grey, or lead coloured: generally friable and flakey, but ſometimes forms very hard lumps. It does not readily fall to pieces in water. It chips and moulders by expoſure to the air and moiſture, but ſlowly. It effervesces with acids; but

but the reſiduum, after ſolution, will not form a brick.

Limeſtone-Gravel. This is a marl mixed with large lumps of limeſtone. The marl may be either calcareous or argillaceous; but moſt commonly the former. The ſandy part is alſo commonly calcareous.

Gypſum is a compound of calcareous earth and vitriolic acid: it forms a diſtinct ſpecies of the calcareous genus of foſſils: of which ſpecies there are ſix families.

The general character of this ſpecies are,

1. *Solubility* in about 500 times its weight of water, in the temperature of 60°.

2. *Precipitability* therefrom by all mild alkalis, and alſo by cauſtic fixed, but not by cauſtic volatile alkali.

3. *Ineffervescence* with acids, if the gypſum be pure; but ſome families of this ſpecies, being contaminated with mild calx, ſlightly effervesce.

4. *Inſolubility*, or nearly ſo in the nitrous acid, in the uſual temperature of the atmoſphere.

5. *A ſpecific gravity*, reaching from, 2,16 to 2,31.

6. A

6. A degree of *hardneſs*, ſuch as to admit being ſcraped by the nail.

7. When heated nearly to redneſs it calcines; and if then it be ſlightly ſprinkled with water, it again concretes and hardens.

8. It promotes putrefaction in a high degree.

Of the ſix families of this ſpecies I ſhall deſcribe only one; namely, that which has been moſt advantageouſly employed as a manure. Deſcriptions of the other five ſhould be found in treatiſes of mineralogy. It is called *fibrous gypſum*.

Its colours are grey, yellowiſh or reddiſh, or ſilvery white, or light red, or browniſh yellow, or ſtriped with one or more of theſe dark colours. It is compoſed of fibres or ſtriæ, either ſtraight or curved, parallel or converging to a common centre, ſometimes thick ſometimes fine and ſubtile, adhering to each other, and very brittle: its hardneſs ſuch as to admit being ſcraped with the nail: commonly ſemitranſparent; in ſome, often in a high degree.

Aſhes. Sifted coal-aſhes, thoſe of peat and white turf-aſhes, have been found uſeful; red turf aſhes uſeleſs, and generally hurtful.

Wood-aſhes have alſo been employed advantageouſly in many caſes; they contain either the four primitive earths, as Mr. Bergman aſſerts; or calcareous earth chiefly, according to Achard; or calcareous and magneſia, according to D'Arcet. They alſo contain ſome proportion of phoſphorated ſelenite, *i. e.* calcareous earth united to the phoſphoric acid. Almoſt all contain alſo a ſmall and variable proportion of common ſalt, Glauber's ſalt, and terrene ſalts, which, when in a ſmall doſe, all accelerate putrefaction; alſo ſmall bits of charcoal.

Charcoal is a ſubſtance well known; it has frequently and ſucceſsfully been uſed as a manure. 1ſt Young's Annals, 152, &c. &c.

Soap-boilers Waſte forms an excellent manure for ſome ſoils; it contains, by Mr. Ruckert's Analyſis, 57 per cwt. of mild calx, 11 of magneſia, 6 of argill, and 21 of ſilex.

Stable Dung. This is uſed either freſh or putrefied; the firſt is called *long*, the other *ſhort dung*; it abounds in animal matter, eaſily runs into putrefaction, and when putrefied ſerves as a leaven to haſten the decay of other dead

dead vegetable ſubſtances; its fermentation is promoted by frequent agitation and expoſure to the air: yet it ſhould be covered to prevent water from carrying off moſt of its important ingredients; or at leaſt the water that imbibes them ſhould not be loſt.

Farm-yard Dung conſiſts of various vegetables; as ſtraw, weeds, leaves, fern, &c. impregnated with animal matter; it ferments more ſlowly than the former; ſhould be piled in heaps, and ſtirred, from time to time. Fern putrefies very ſlowly. The water that iſſues from it ſhould be preſerved.

Some of theſe manures have been analyzed.

Table of Contents of Manures.

105 lb.	Heavy Inflam. Air. Cub. Inc.	Fixed Air Cub. Inc.	Water lb.	Coal. lb.	Calx and Magnefia. lb.	Argill lb.	Silex lb.	Vol. Alk. lb.	Fixed Salts. lb.
Freſh Cow-dung *	—	—	—	3,75	1, 2	0,15	2, 4	—	0, 6
Freſh Horſe-dung *	—	—	88	10,2	1, 5	0,5	,3	—	0,21
Sheeps dung * -	—	—	—	25,0	9,28 Calx 1, Mag.	3	49	—	0,72
Rotten Cow dung *	1360	120	81 Water and Oil	10	3.	0,16	5	0,65	Gypſ. 0, 9 F. Salts 0,24
Earth reſulting from rotten Horſe-dung†	1.64	1.	38,15	18,75	6, 2	1, 5	23,43		
Soap-boilers Waſte *	—	—	—	—	57 Calx 11 Mag.	6,	41,		

* 2 Ruckert. † In Encycloped. Art. Vegetation. *Hallenfeas*

Hence

Hence they ſhould be applied, not indiſcriminately, but according to circumſtances, to be indicated in the ſequel.

Pounded bones form alſo manure much uſed in the neighbourhood of great towns. They gradually depoſit their oily part, which contains a large proportion of animal coal which is extricated by putrefaction, and phoſphorated calx. Hence Bone-aſh is alſo uſeful.

Sea-weed, particularly if mixed with earth, ſoon putrefies, and makes a good manure.

Sweepings of Ditches abound with putrid matter from decayed vegetables, and hence form a manure.

Old Ditches, expoſing a large ſurface to vegetation, contain, when deſtroyed, a quantity of decayed vegetables, which putrefy and make a good manure; but in this and the former caſe, it may be proper to diſtinguiſh of what ſoil they are compoſed, for reaſons that will hereafter appear.

Fallowing, is the principal operation by which exhauſted lands are reſtored to fertility; its uſe ſeems to me to conſiſt in expoſing the roots of vegetables to decay, whereby food for a freſh

growth is prepared; the atmoſphere alſo dèpoſits fixed air and carbonaceous ſubſtance on earth long expoſed to it.

Draining, is an operation equally neceſſary and well known, on which no more need be ſaid here.

Paring and burning reduces the roots of vegetables to coal and aſhes; and thus prepares both a ſtimulant and nutriment for plants, as will be ſeen hereafter.

CHAP II.

OF THE FOOD OF PLANTS, AND THE COMPOSITION OF FERTILE SOILS.

HAVING in the preceding chapter explained the nature of the different ſoils known in agriculture, and of the different manures whoſe general utility has been aſcertained by long experience, we are now to enquire which of thoſe manures are moſt advantageouſly applicable to each

each of thoſe particular ſoils, and what are the cauſes of their beneficial effect in each particular inſtance.

To proceed with order in this enquiry, we muſt obſerve that the general effect expected from the application of manure is fertility; that is, the moſt copious production of corn and graſſes; and, ſince fertility is itſelf the reſult of the due adminiſtration of the food of thoſe vegetables, we muſt firſt ſee what that food is, and of what ingredients a ſoil ought to be compoſed, in order to contain or adminiſter it; after which we ſhall indicate by what manures each particular ſort of ſoil is brought into a fertile ſtate (which is the beneficial effect expected from them) and how in each particular caſe they contribute to the due adminiſtration of the vegetable food, which is the cauſe of their beneficial effect.

SECTION I.

Of the Food of Plants.

To diſcover the food of plants, particularly of thoſe which form the object of our preſent

enquiry, we muſt examine the nature and proportion of the ſubſtances in which they grow, and of thoſe which they themſelves contain: thus we ſhall be enabled to ſee which of the latter are derived from the former.

Firſt, All plants (except the ſubaqueous) grow in a mixed earth, moiſtened with rain and dew, and expoſed to the atmoſphere. If this earth be chemically examined, it will be found to conſiſt of ſilicious, calcareous, and argillaceous particles, often alſo of magneſia, in various proportions, a very conſiderable quantity of water, and ſome fixed air. The moſt fertile, alſo, contain a ſmall proportion of oil, roots of decayed vegetables, a coaly ſubſtance ariſing from putrefaction, ſome traces of marine acid, and gypſum*. On the other hand, if vegetables be analyzed, they will be found to contain a large proportion of water and charcoal; alſo fat and eſſential oils, reſins, gums, and vegetable acids: all which are reducible to water, pure air, inflammable air and charcoal: a ſmall proportion of fixed alkali is alſo found,

* Home, 15 Mem. D'Agriculture, Par. 1790. Encyclop. *Vegetation*, P. 277.

ſome

ſome neutral ſalts, moſt commonly gypſum, tartar vitriolate, common ſalt, and ſalt of ſylvius. In corn, and particularly wheat, phoſphorated ſelenite is alſo found.

Hence we ſee that, on the laſt analyſis, the only ſubſtances common to the growing vegetables and the ſoils in which they grow, are water, coal, different earths, and ſalts. Theſe, therefore, are the true food of vegetables: to them we ſhould alſo add fixed air, though, by reaſon of its decompoſition, it may not be diſtinctly found in them, or at leaſt not diſtinguiſhable from that newly formed during *their decompoſition.*

I ſhall now examine the ſeparated functions of each of theſe ingredients.

Of Water.

The agency of water in the proceſs of vegetation, has never been doubted, though the manner in which it contributes to it has not, until of late, been diſtinctly perceived. Doctor Hales has ſhewn that in the ſummer months a ſun-flower, weighing three pounds avoirdupois,

pois, and regularly watered every day, paſſed through it, or perſpired, 22 ounces each day; that is, nearly half its weight. He alſo found that a cabbage-plant, weighing, 1 lb. 9 oz. ſometimes perſpired 1 lb. 3 oz.; but at a medium about half its weight *. Doctor Woodward found that a ſprig of common ſpearmint, a plant that thrives beſt in moiſt ſoils, weighing only 28,25 grs. paſſed through it 3004 grs. in 77 days, between July and October; that is, ſomewhat more than its own weight each day. He did more; for he found that in that ſpace of time the plant increaſed 17 grs. in weight, and yet had no other food but pure rain water. But he alſo found that it increaſed more in weight when it lived on ſpring-water, and ſtill more when its food was Thames water †. From whence we may deduce that graſſes and corn, during the time of their growth, abſorb about one half their weight of water each day if the weather be favourable.

Secondly, That the water they thus paſs nouriſhes them merely as water, without tak-

* 1 Hales, 9, 10, 15. † 2 Phil. Tranſ. Abr. 716.

ing

ing any foreign ſubſtance into the account; for 3000 grs. of rain water, in Doctor Woodward's experiment, afforded an increaſe of 17 grains; whereas by Margraaff's experiments, 5760 grs. of that water contain only one third of a grain of earth *. But,

Thirdly, It alſo follows, that water contributes ſtill more to their nouriſhment when it conveys to them earthy and ſaline particles, as ſpring and Thames waters do.

The manner in which pure water contributes to the nouriſhment of plants, beſides the ſervice it renders them in diſtributing the nutritive parts throughout their whole ſtructure, and forming itſelf a conſtituent part of all of them, may be underſtood from modern experiments. Doctor Ingenhouz and Mr. Senebier have ſhewn that the leaves of plants expoſed to the ſun produce pure air: now water has of late been proved to contain about 87 per cwt. of pure air, the remainder being inflammable air. Water is then decompoſed by the aſſiſtance of light within the vegetable; its

* 2 Margr. 6, 70.

inflammable

inflammable part is employed in the formation of oils, reſins, gums, &c.; its pure air is partly applied to the production of vegetable acids, and partly expelled as an excrement.

Many indeed have aſſerted that water is the ſole food of vegetables; and among the experiments adduced to prove it, that of Van Helmont, quoted by the illuſtrious Mr. Boyle *, is by far the moſt ſpecious. He planted a trunk of willow, weighing 5 lb. in an earthen veſſel filled with earth dried in an oven, and then moiſtened with rain-water. This veſſel, it appears, he ſunk in the earth, and watered partly with rain-water, and occaſionally with diſtilled. After five years he found the tree to weigh 169 lb. and the earth in which it was planted, being again dried, to have loſt only 2 oz. of its former weight, though the tree received an increaſe amounting to 164 lb.

Before I proceed to the explication of this experiment, I muſt remark ſome circumſtances attending it: Firſt, that the weight of the earth contained in the veſſel at the commencement and at the end of five years, could not

* 2d Shaw's Boyle, 240.

be

be exactly compared, because the same degrees of deficcation could not be exactly ascertained, and because many of the fibrillæ of the roots of the tree must have remained in the earth after the tree was taken out of the vessel, and these must have prevented the true loss of earth from being perceived. Secondly, That the earthen vessel must have frequently absorbed water impregnated with whatever substance it might contain, from the surrounding earth in which it was inserted; for unglazed earthen vessels easily transmit moisture. (1st Hales 5, and Tiller's Mem. Par. 1772, page 298, 304, 8vo,) Thirdly, As it appears that the pot was sunk in the earth, and received rain-water, it is probable that distilled water was seldom used.

These circumstances being considered, it will easily be made to appear that the rain-water, absorbed by the tree, contained as much earth as the tree can be supposed to contain.

First, The willow increased in weight 164 lb. in five years; that is, at the rate of 2,7 lb. nearly per month; and it being an aquatic, it cannot be supposed to pass less than its own weight of water each day during the six vege-

tating

rating months. In the firſt month therefore, it abſorbed and paſſed $5 \times 30 = 150$ lb. and as each pound of rain water contains $\frac{1}{7}$ gr. of earth, 50 grains of earth muſt have been depoſited in the plant; and allowing no more than 50 grains for the depoſit of each of the ſix months, we ſhall have $50 \times 6 = 300$ for the depoſit of the firſt year: but at the end of the firſt year the plant gains an acceſſion of 32 lb. therefore in each of the ſix ſummer months of the ſucceeding year, it paſſes $37 \times 30 = 1110$ lb. of water, and receives a depoſit of 370 grains; and at the end of the ſecond year the depoſit amounts to 2220 grains. At the commencement of the third year, the tree gaining a farther acceſſion of 32 lb. muſt weigh 69 lb. and paſs in each of the ſummer months $69 \times 30 = 270$ lb. of water, and receive a depoſit of 690 grs. which multiplied into $6 = 4140$ grains. At the commencement of the fourth year, the tree ſtill gaining 32 lb. muſt weigh 101 lb.; and if it paſſes 101×30 in each of the ſummer months, it muſt gain a depoſit in each of 1010 grs. of earth, and at the end of the year 6060. At the commencement of the fifth year it weighs

weighs 133 lb. and gains at the end of the ſix months 23940 grains of earth. The quantities of earth depoſited each year exceed 5 lb. avoirdupois, a quantity equal to that which 169 lb. of willow can be ſuppoſed to contain; for the commiſſioners employed to inſpect the fabrication of ſaltpetre in France, having examined the quantities of aſhes afforded by trees of various kinds, found that 1000 lb. of ſally, a tree much reſembling the willow, afforded 28 lb. of aſhes, and conſequently 169 lb. ſhould produce 4,7. I do not give this calculation, however, as rigorouſly exact. It is certain that if the depoſit left at the end of every month were exactly taken, the total would exceed the quantity juſt mentioned; but that, found even by this rude mode, ſufficiently proves that water conveys a portion of earth into vegetables equal to any that the experiments hitherto made can prove to exiſt in them.

As to the coal, or carbonaceous principle, which this willow muſt alſo have contained, it is probable that much of it exiſted in the earth in which the willow grew. Some is contained in all moulds or vegetable earth; and as we are

not told what ſort of earth Van Helmont uſed, we may well ſuppoſe it was good vegetable earth, its quantity amounting to 200 lb. This principle may alſo have been contained in the water, for the pureſt rain water contains ſome oleaginous particles, though in an exceeding ſmall proportion, as Mr. Margraaf has obſerved *; and all oil contains coal. Some alſo may have paſſed from the ſurrounding vegetable earth through the pores of the earthen veſſel. All the other experiments, adduced to prove that water is the ſole food of plants, may be explained in the ſame manner. Grains of wheat have been made to grow on cotton moiſtened with water; each produced an ear, but that ear contained but one grain †. Here the carbonaceous ſubſtance was derived from the grain, and afterwards diffuſed and tranſported through the whole plant by the water abſorbed; for it muſt be obſerved that grain, like an egg, contains much of the nouriſhment of its future offspring. It is thus that tulips, hyacinths, and other plants, expand and grow in mere water.

* 2d Marg. 15,90. † 2d Young's Annals, 487.

The

The earth contained in rain-water is united partly with the nitrous and marine acids, as Margraaf has ſhewn, but far the greater part only with fixed air; for the feeble traces of the two former acids could not hold in ſolution the 100 grains of earth which he found in 300 lb. of rain-water.

By far the greateſt proportion of vegetable ſubſtances conſiſts of water. According to Mr. Young and Ruckert, graſs loſes about $\frac{2}{3}$ of its weight on being dried into hay *. Dr. Hales found a ſun-flower plant, which weighed 48 ounces, to loſe 36 ounces by drying in the air during thirty days †, and conſequently to have loſt 3-fourths of its weight. Even vegetables to appearance thoroughly dry, contain from 3-fifths to 3-fourths of their weight of water ‡. This water is not all in a liquid ſtate, but, by the loſs of much of its ſpecific heat, is in a great meaſure ſolidified.

Of Coal, or the Carbonic Subſtance.

To Mr. Haſſenfraz we owe the diſcovery, that coal is an eſſential ingredient in the food

* 2d Young's An. 26. 2d Ruck. 139. † 1ſt Hales, 8.
‡ Ruckert, 28. Seneb. Encyclop. Vegetation. 52.

of all vegetables. Though hitherto little attended to, it appears to be one of the primæval principles, as ancient as the preſent conſtitution of our globe: for it is found in fixed air, of which it conſtitutes above one-fourth part; and fixed air exiſts in lime-ſtones and other ſubſtances, which date from the firſt origin of things.

Coal not only forms the reſiduum of all vegetable ſubſtances that have undergone a ſlow and ſmothered combuſtion, that is, to which the free acceſs of air has been prevented, but alſo of all putrid vegetable and animal bodies: hence it is found in vegetable and animal manures that have undergone putrefaction, and is the true baſis of their ameliorating powers: if the water that paſſes through a putrefying dunghill be examined, it will be found of a brown colour; and if ſubjected to evaporation, the principal part of the reſiduum will be found to conſiſt of coal *. All ſoils ſteeped in water communicate the ſame colour to it in proportion to their fertility; and this water being evaporated, leaves alſo a coal, as Mr. Haſſenfraz and Fourcroy atteſt †. They alſo

* 14 An. Chy. 56. † Ibid.

obſerved,

obſerved, that ſhavings of wood being left in a moiſt place for nine or ten months, began to receive the fermentative motion, and being then ſpread on land, putrefied after ſome time, and proved an excellent manure *. Coal, however, cannot produce its beneficial effects but in as much as it is ſoluble in water. The means of rendering it ſoluble are not as yet well aſcertained; nevertheleſs, it is even now uſed as a manure, and with good effect †. In truth, the fertilizing power of putrid animal and vegetable ſubſtances were fully known even in the remoteſt ages, but moſt ſpeculatiſts have hitherto attributed them to the oleaginous, mucilaginous, or ſaline particles then developed, forgetting that land is fertilized by *paring* and *burning*, though the oleaginous and mucilaginous particles are thereby conſumed or reduced to a coal, and that the quantity of mucilage oil or ſalt in fertile land is ſo ſmall, that it could not contribute the 1000th part of the weight of any vegetable; whereas coal is ſupplied not only by the land, but alſo by

* 14 An. Chy. 56. † Young's Annals.

the fixed air combined with the earths, and alſo by that which is conſtantly ſet looſe by various proceſſes, and ſoon precipitates by the ſuperiority of its ſpecific gravity, and is then condenſed in, or mechanically abſorbed by ſoils, or contained in dew. Lands which contain iron in a ſemicalcined ſtate, are thereby enabled to decompoſe fixed air, the iron, by the help of water, gradually attracting the pure air, which enters into the compoſition of fixed air, as Mr. Gadolin has ſhewn *: a diſcovery which appears to me among the moſt important of theſe later times; but theſe calces of iron may again be reſtored to their former ſtate by union with oleaginous ſubſtances, as Mr. Beaumè has noticed: and this is one of the benefits reſulting from the application of dung before it has fully putrefied †. Hence we may underſtand how ſoils become effected and exhauſted, this effect ariſing in great meaſure from the gradual loſs of the carbonic principle depoſited by vegetable and animal manures,

* 1ſt Chym. Ann. 1791, 53.

† The affinities of coal and iron to pure air, vary with the temperature.

and

and from them paſſing into the growing vegetables; and alſo from the loſs of the fixed air contained in the argillaceous part of the ſoil, which is decompoſed by vegetables; and from the calcination of the ferruginous particles contained in the ſoil. I ſay in *great meaſure*, becauſe other cauſes contribute to the diminution of fertility; which ſhall preſently be mentioned. Hence alſo we ſee why lands paſtured remain longer fertile than thoſe whoſe vegetable crop is carried off, as much of the carbonaceous principle is reſtored by the excrements of the paſturing animals: why ſome crops exhauſt more than others; becauſe corn, and particularly wheat, contains more of the carbonic principle than graſſes, and very little of its exuviæ are left behind: why fallows are of ſome uſe; as the putrefaction of the roots of weeds and the abſorption of fixed air by clays, are thereby promoted: why vegetables thrive moſt in the vicinity of towns; becauſe the carbonic principle is copiouſly diſperſed by the ſmoke of the various combuſtibles conſumed in inhabited places: why ſoot is ſo powerful a manure: why burning the clods of graſſy land

contributes ſo much to its fertility, and then only when the fire is ſmothered and coal produced; beſides many other agricultural phenomena, too tedious to relate: but I muſt not omit that the phoſphoric acid is found in coal; and this enters into the compoſition of many vegetables.

The quantity of coal in vegetables is various, according to their various ſpecies, age, and degrees of perfection: wood and corn contain moſt, graſſes leaſt. Weigleb found dry beech-wood to contain one fifth of its weight of coal *. Weſtrumb found *trifolium pratenſe*, a ſort of clover, to contain about one ſeventh. Hence, after water, it is the moſt copious ingredient in vegetables.

Of Earths.

The next moſt important ingredient to the nouriſhment of plants is earth: and of the different earths the calcareous ſeems the moſt neceſſary, as it is contained in rain-water: and, abſolutely ſpeaking, many plants may grow

* Uber die alkalis, p. 76.

without

without imbibing any other. Mr. Tillet found corn would grow in pounded glaſs *; Mr. Succow in pounded fluor ſpar, or ponderous ſpar, or gypſum †: but Tillet owns it grew very ill; and Haſſenfraz, who repeated this experiment, found it ſcarcely grow at all when the glaſs or ſand were contained in pots that had no hole in the bottom, through which other nutritive matter might be conveyed. It is certain, at leaſt from common experience, that neither graſſes nor corn grow well either in mere clay, ſand, or chalk; and that in vegetables that grow moſt vigorouſly, and in a proper ſoil, three or four of the ſimple earths are found. Mr. Bergman, on the other hand, aſſures us he extracted the four earths, the ſilicious, argillaceous, calcareous and muriatic, in different proportions from the different ſorts of corn ‡. Mr. Ruckert, who has analyzed moſt ſpecies of corn and graſſes, found alſo the four above-mentioned earths in various proportions in all of them. Of his analyſis I ſhall here give a ſpecimen, comprehending however the calcareous and

* Mem. par. 1772, 301, 8vo. † 1ſt Chym. An. 1784.
‡ 5 Bergman, 94, 98. Schœffer Worles, ſec. 172.

muriatic in the ſame column, as this laſt ſcarcely deſerves particular notice:

One hundred parts of the lixiviated aſhes of

	contained of Silex.	Calx.	Argill.
Wheat	48pts.	37	15
Oats	68	26	6
Barley	69	16	15
Bere	65	25	10
Rye	63	21	16
Potatoes	4	66	30
Red Clover	37	33	30

Mr. Ruckert is perſuaded that earth and water, in proper proportions, form the ſole nutriment of plants; but Mr. Giobert has clearly ſhewn the contrary; for, having mixed pure earth of alum ſilex, calcareous earth, and magneſia, in various proportions, and moiſtened them with water, he found that no grain would grow in them; but when they were moiſtened with water from a dunghill, corn grew in them proſperouſly *. Hence the neceſſity of the carbonic principle is apparent.

The abſolute quantity of earth in vegetables is very ſmall. Dr. Watſon informs us that

* Encyclop. *Vegetation*, 274.

106 avoir-

106 avoirdupois pound = 1696 ozs. of oak, being carefully burned, left but 19 ozs. of aſhes; and from theſe we muſt deduct 1,5 for ſalt, then the earthy part amounts only to 17,5; that is, little more than one per cwt. The commiſſioners appointed to inſpect the ſaltpetre manufactory, found nearly the ſame reſult; namely, 1,2 per cwt. in beech 0,453, and in fir only 0,003. Hence we need not wonder at trees growing among rocks where ſcarce any earth is to be ſeen; but in the ſtalks of Turkey-wheat, or maize, they found 7 per cwt. of earth, in ſun-flower plant 3,7 *; ſo that, upon the whole, weeds and culmiferous plants contain more earth than trees do. Mr. Weſtrumb found *trifolium pratenſe* to contain about 4,7 per cwt. of earth, of which 2 per cwt. was mild calx, nearly 2 more ſilex, 0,7 argill, together with a ſmall proportion of phoſphorated iron, calx of iron, and manganeſe †.

Since plants derive ſome proportion of earth from the ſoil on which they grow, we cannot

* See 3 Tranſ. Royal Iriſh Academy.
† 1ſt Chy. An. 1787.

be

be ſurprized that theſe ſoils ſhould at length be exhauſted by crops that are carried off; ſuch as thoſe of corn and hay, particularly the former: even lands paſtured muſt at laſt be exhauſted, as the excrements of animals do not reſtore the exact quantity that the animals have conſumed; and hence the utility of mucks, as the reſtoration is performed by more animals than have been employed in the conſumption. Hence alſo a ſucceſſion of different crops injures land leſs than a ſucceſſion of crops of the ſame kind, as different proportions of the different earths are taken up by the different vegetables. Finally, we may hence derive the utility of marling land, as the deficient earths are thereby replaced. This ſubject admits of more preciſion than has been hitherto imagined, and may even be ſubjected to calculation. The abſolute quantity and relative proportions of the various earths in an acre of land may be determined, ſo may that in the crops of different vegetables; and by comparing both, the *time* alſo may be found in which the land muſt be exhauſted, unleſs renovated by various manures: thus the neceſſity of marling. The

kind

kind of marl or other manures, and the quantity neceſſary to an acre of land, may be very nearly aſcertained.

Earths cannot enter into plants but in a ſtate of ſolution, or at leaſt only when ſuſpended in water in a ſtate of diviſion as minute as if they had been really diſſolved. That ſilicious earth may be ſuſpended in ſuch a ſtate of diviſion appears from various experiments, particularly thoſe of Mr. Bergman, who found it thus diffuſed in the pureſt waters of Upſal; and it is equally certain that it enters copiouſly into vegetables. Both his experiments, and eſpecially thoſe of Mr. Macie, eſtabliſh this point beyond contradiction *. Argillaceous earth may alſo be ſo finely diffuſed as to paſs through the beſt filters; ſo alſo may calx, as appears from the quantity Margraaf found in the pureſt rain-water. This earth is even ſoluble by means of an exceſs of fixed air in about 1500 times its weight of water. It may alſo be and moſt frequently is converted into gypſum by the vitriolic acid which moſt clays

* Phil. Tranſ. 1791.

contain,

contain, as Mr. Morveau has ſhewn *, and then it is ſoluble in 500 times its weight of water.

Vegetables not only require food, but alſo that this food be duly adminiſtered to them: a ſurfeit is as fatal to them as abſolute privation. Doctor Hales obſerved that a young pear-tree, whoſe roots were ſet in water, abſorbed a ſmaller quantity of it every day, the ſap-veſſels being ſaturated and clogged by it; and Mr. Miller found that too much water rotted the young fibres of the roots as faſt as they puſhed out †. Saturated ſolutions of dung appeared to Mr. Du Hamel equally hurtful ‡. Now the preſervation and due adminiſtration of this liquid food is effected by due proportions of the ſimple earths and their looſe or condenſed ſtate. Their ſituation in other reſpects being the ſame, thoſe that abound in the argillaceous principle are the moſt retentive of water; thoſe that abound in the coarſe ſilicious, leaſt; the calcareous being intermediate be-

* 1ſt Encycloped. Chymic. 123.
† 1ſt Hales, 17.
‡ Mem. Par. 1748.

tween

tween both; various ſpecies of vegetables requiring various quantities of water and other food: hence it is that every ſort of ſoil bears vegetables peculiarly adapted to it, while others do not grow at all, or but ill in it. By the experiments of Mr. Bergman, we find that

Argill takes up 2,5 times its weight of water when ſaturated ſo as to let none drop.

Magneſia	-	1,05
Chalk	-	0, 5.
Silicious Sand	-	0,25

Fixed Air.

That plants do not thrive, but moſt frequently periſh, when ſurrounded by an atmoſphere of fixed air, has long been obſerved by that great explorer of the moſt hidden proceſſes of nature, Doctor Prieſtly; but that fixed air imbibed by the roots is favourable to their growth, ſeems well eſtabliſhed by the experiments of Doctor Perceval of Mancheſter, and fully confirmed by thoſe of Mr. Ruckert. This laſt-mentioned philoſopher planted two beans in pots of equal dimenſions filled with

with garden-mould. The one was watered almoſt daily with diſtilled, the other with water impregnated with fixed air, in the proportion of half a cubic inch to an ounce of water; both were expoſed to all the influences of the atmoſphere, except rain. The bean treated with aerated water appeared over ground nine days ſooner than that moiſtened with diſtilled water, and produced 25 beans; whereas the other pot produced only 15. The ſame experiment was made on ſtock-july-flowers and other plants with equal ſucceſs*. The manner in which fixed air acts in promoting vegetation, ſeems well explained by Mr. Senebier: he firſt diſcovered that freſh leaves expoſed to the ſun in ſpring-water, or water ſlightly impregnated with fixed air, always produce pure air as long as this impregnation laſts; but as ſoon as it is exhauſted, or if the leaves be placed in water out of which this air has been expelled by boiling, they no longer afford pure air †: from whence he infers that

* 2d Chy. An. 1788, 399.
† Sur l'Influence de la Lumiere, & 41 Roſier, 206.

fixed

fixed air is decompoſed, its carbonic principle retained by the plant, and its pure air expelled. It appears to me alſo, by acting as a ſtimulant, to help the decompoſition of water. Mr. Haſſenfraz, indeed, denies its decompoſition; but his arguments do not appear to me concluſive, for reaſons too tedious and technical to mention here. The vitriolic acid contained in various clays brought into multiplied contact with calcareous earth by the agitation of ſoils in agricultural operations, and the motion of the roots, gradually ſets looſe the fixed air contained in this laſt-mentioned earth; that portion alſo of this earth, which is by water introduced into the plant, is decompoſed, and its air ſet looſe by the vegetable acids of the plant.

Of Saline Subſtances.

Saline ſubſtances (gypſum and phoſphorated calx excepted) ſeem to ſerve vegetables (as they do animals) rather as a *condimentum*, or promoter of digeſtion, than as a *pabulum*. This idea is ſuggeſted by the ſmallneſs of their quantity,

quantity, and the offices they are known to perform. Their quantity is always ſmaller than that of earth; and this we have already ſeen to be exceeding ſmall.

Thus, one thouſand pound of	lb.
Oak gives of ſaline matter only	1,5
Elm - - - -	3,9
Beech - - -	1,27
Fir - - - -	0,45
Vine branches - -	5,5
Fern - - - -	4,25
Stalks of Turkey wheat -	17,5
Wormwood - - -	73,
Fumitory - - -	79,
Trifolium pratenſe - -	0,78
Vetches * - - -	27,5
Beans with their ſtalks * -	20,

In all the experiments hitherto made, the proportion of ſaline matter to the earthy has been found ſmalleſt in woods. In other plants, generally as 1 to 1,3, 1,5, or 2; however, Mr. Ruckert has marked ſome exceptions, which I ſhall mention as worthy of notice.

* 3 Ruck. 49.

Proportion

Proportion of Saline Subſtances to the Earthy.

In Hemp	-	as	1 to 8.
Flax	-	-	1 to 1,7 nearly.
Parſnips	-	-	1,1 to 1.
Potatoes	-	-	1 to 1,3
Turnips	-	-	1 to 3,33
Wheat	-	-	1 to 3.
Rye	-	-	1 to 8.
Oats	-	-	1 to 8.

Theſe proportions have ſome analogy with the quantity and ſort of manure proper to be employed in the cultivation of theſe plants and the ſucceſſion of crops. But I ſhall enter no farther into this ſubject, as it would lead me too far from the preſent object of enquiry.

The ſalts generally extracted from the aſhes of vegetables, are tartar vitriolate, Glauber's ſalt, common ſalt, ſalt of Sylvius, gypſum, phoſphorated calx, and fixed alkalis.

Alkalis ſeem to be the product of the vegetable proceſs, for either none or ſcarce any is found in the ſoils, or in rain-water, while in the vegetable they are moſt probably neutralized,

partly by vegetable acids which are decompoſed in the proceſs of combuſtion, and partly by the vitriolic and marine acids. Weſtrumb found tartar vitriolate and digeſtive ſalts in the juices of trifolium.

Gypſum probably exiſts in greater quantity in plants than it appears to amount to after combuſtion and lixiviation; much of it muſt be decompoſed during the combuſtion, and ſtill more during lixiviation, by the alkalis exiſting in the ſolution. Thus the apparent quantity of tartar vitriolate is increaſed.

Phoſphorated Calx is found in greateſt quantity in wheat, where it contributes to the formation of the animal gluten. Hence in rainy years the quantity of gluten in wheat has been obſerved to be ſmaller *. Hence the excellence of bone-aſhes as a manure for wheat; and hence wheat ſucceeds beſt after clover, if the clover be fed off, but not if it be mowed †, as much of the phoſphoric acid is communicated by the dung of animals.

The chief uſe of tartar vitriolate ſeems to

* 2d Witwer's Diſſertations, 103.
† 2d Young's Annals, 36, 37.

be,

be, that it promotes the decompoſition of water, as Mr. Senebier has obſerved *.

Section II.

Of the Conſtitution of Fertile Soils, and the Method of eſtimating their Fertility.

The moſt fertile ſoil is that which contains the greateſt quantity of the food of thoſe vegetables that nouriſh men and uſeful animals, and adminiſters it to them with due œconomy.

The firſt eſſential requiſite, therefore, to a fruitful ſoil is, that it contain a ſufficient quantity of the three or four ſimple earths above mentioned, and of the ſoluble carbonaceous principle. The other requiſites are, that the proportion of each, and general texture of the ſoil, be ſuch as to enable it to admit and retain as much water as is neceſſary to vegetation, and no more.

Now we have already ſeen that the retentive powers of moiſture are very different in the

* Sur la Lumiere, p. 130.

ſimple earths: therefore tne proportions in which the fertility of a ſoil requires them to be mixed, muſt be different in climates and countries that differ conſiderably in moiſture; in the *drier*, they muſt be ſuch as are moſt retentive; in the *moiſter*, ſuch as ſuffer it to paſs or evaporate more eaſily.

The ſame remark extends to ſituation. Lands on a plain ſhould be ſo conſtituted as to be leſs retentive of water than thoſe ſituated on a declivity; as is very evident.

So lands that have a retentive or impermeable ſubſoil, ſhould be differently conſtituted from thoſe that have one leſs retentive or more permeable. The time of the year in which rain moſt abundantly falls may alſo be worthy of notice.

Theſe circumſtances muſt undoubtedly modify the concluſions that may be drawn from the experiments I ſhall now relate.

Analyſis of a Fertile Soil in a very rainy Climate.

Mr. Giobert has communicated to the public, the analyſis of a fertile ſoil in the vicinity of

of Turin, where it rains yearly above 40 inches on the ſquare foot. He found 1lb of it to contain from 20 to 30 grains of extractive matter which flamed and burned, and therefore was a coal ſoluble in water; 26 lb. of it contained 1808 grains of water. The ſimple earths were in the following proportion per cwt *.

Silex, from	—	77 to	79
Argill —	—	9 —	14
Calx —	—	5 —	12

Hence the pound ſhould contain †,

			grs.
Carbonic matter	—		25
Water	—	—	70
Silex, from	4362	to	4475
Argill —	509	—	793
Calx —	283	—	679

He alſo found it to contain a great deal of air (about 19 grains) of which one-third was fixed, and the remainder heavy inflammable air; but no volatile alkali.

* Encyclop. *Vegetation*, 276.

† The Turin medicinal pound is divided like the troy, and contains the ſame number of grains.

The weight of a cubic foot of this ſoil does not appear, nor is its ſpecific gravity given; hence neither its texture, nor the quantity of each ingredient, can be directly aſcertained; yet, from the neceſſity of its being in ſome degree open, and the weights of good ſoil found by Mr. Fabroni *, I conclude its ſpecific gravity cannot exceed 1,58; then a cubic foot of it ſhould weigh about 120 lb. troy, or 100 avoirdupois.

In leſs fertile ſoils, Mr. Giobert found the proportions of

Silex,	from	48	to 80
Argill	—	7	— 22
Calx	—	6	— 11

Hence the troy pound contained, of

Silex,	from	2716	to 4528
Argill	—	396	— 1245
Calx	—	339	— 622

allowing 100 grains for moiſture, as either the calx or argill exceeds the proportions in more fertile lands.

The ſpecific gravity of theſe ſoils is not

* 8 Young's Annals, 174.

given;

given; but it probably exceeds or falls ſhort of that of the more fertile ſoils.

In Barren Soils,

The proportions of Silex, from 42 to 88
Argill — 20 — 30
Calx — 4 — 20

Hence the troy pound contained, allowing for water 120 grains,

Silex, from 2368 to 4963
Argill — 1128 — 162
Calx — 225 — 620

The ſpecific gravity of theſe ſoils is not given; but it probably is either much above or much below that of the former, as they are either too cloſe or too open. Mr. Fabroni found that of barren ſandy land 2,21.

Note alſo, that if the proportion of water be different from that here ſuppoſed, the contents of the troy pound will alſo be different; but may be eaſily rectified.

Analyſis of a Fertile Soil, where the Fall of Rain is 24 Inches.

Mr. Bergman found that a fertile ſoil, ſituated on a plain, where the yearly fall of rain amounts to 15 Swediſh (that is 23,9 Engliſh) inches, contained four parts clay, three of ſilicious ſand, two of calcareous earth, and one of magneſia (in all ten parts;) but the laſt not being of abſolute neceſſity, may be annexed to the calcareous.

The compoſition of the clay he does not expreſsly mention, but we may ſuppoſe it ſuch as moſt frequently occurs, containing 66 per cwt. of fine ſilicious ſand, and 34 of mere argill; conſequently 0,40 of it contain nearly 0,14 of mere argill; and 0,26 of fine ſilicious ſand.

The ſilicious ſand, mentioned by Mr. Bergman, is what we call gravel (conſiſting of ſtone from the ſize of a pea, or leſs, to that of a nut;) and thus he himſelf explains it*. This amounts to 30 per cwt.

* 5 Bergman, 102, 103.

Hence

Hence we may ſtate the proportions thus:

Coarſe Silex	- -	30
Finer	- -	26
		——56 parts
Argill	- -	14
Calx	- -	30
		100

The uſe of the gravel is to keep the ſoil open, and looſe: a circumſtance abſolutely neceſſary, as I have before obſerved.

The ſpecific gravity is not given, but ſhould not much exceed, I ſuppoſe, 1,600. Muſchenbroek found that of garden-mould 1,630. The carbonic matter was not known to Mr. Bergman.

The proportion in a troy pound, ſuppoſing the quantity of water and coal not to exceed 100 grains, ſtands thus, omitting fractions:

Gravel	- -	1698
Fine ſand	- -	1471
		——3169
Argill	- - -	792
Calx	- - -	1698

Here

Here we ſee the quantity of calx much greater than in the ſoil of Turin, where the fall of rain is greater; for in the drier climates there is a neceſſity to retain the rain, and the argill if increaſed would retain it too long and too much; and, beſides, enters very ſparingly into the conſtitution of plants.

The following experiments were made by Mr. Tillet at Paris, where the fall of rain amounts to 20 inches at an average.

He filled with mixtures of different earths a number of pots twelve inches in diameter at the top, ten at the bottom, and ſeven or eight deep. It appears alſo that they were ſo porous as to abſorb moiſture, and that they were perforated at the bottom. Theſe he buried up to the ſurface in a garden, ſowed in each ſome grains of wheat, and then abandoned them to nature.

Fertile Mixtures.

1ſt. The firſt mixture he found fertile conſiſted of three-eighths of the potters clay of Gentilly = 0,375, three-eights of the parings of limeſtone,

ſtone, and two-eights of river ſand = 0,25. In this, the corn grew very well for three years; that is, as long as the experiment laſted.

As potters clay is not pure argill, and as Mr. Tillet does not mention the proportion the mere argillaceous part bore to the ſilicious, I muſt ſupply this defect, by ſuppoſing this clay to contain near one half its weight of pure argill, as it is clay of this ſort that potters generally chuſe; and that of Gentilly is eſteemed one of the beſt. Both the clay and limeſtone, he tells us, were pulverized, that they might more exactly incorporate when mixed. Then the centeſimal proportions will ſtand thus:

Coarſe Silex	-	25
Finer	-	21
		46
Argill	-	16,5
Calx	-	37,5
		100

The quantities in the troy pound, ſuppoſing

ing the water, &c. to amount to 100 grains, are,

Coarſe ſand -	1415	
Finer - -	1188	
		2603
Argill - -		934
Calx - -		2122
		5659

2d. This contained two-eighths of potters clay, three-eighths parings of limeſtone, and three-eighths coarſe ſand. The centeſimal proportions are,

Coarſe ſand -	37,5	
Finer - -	14	
		51,5
Argill - - -		11
Calx - - -		37,5
		100

In the troy pound, ſuppoſing the quantity of water

water to amount to 100 grains, the quantities of the three earths will be,

Coarſe Silex -	2122	
Finer - -	792	
		2914
Argill - -		622
Calx - - -		2122
		5658

Hence we ſee that in the drier countries, where the fall of rain is but 20 inches, the ſoil, to be fertile, muſt be cloſer, and the quantity of calcareous earth much increaſed, and that of the ſilicious much diminiſhed. Thus, in the climate of Turin, where the fall of rain exceeds 40 inches, the proportion of ſilicious earth is from 77 to 80 per cwt. and that of calcareous, from 9 to 14, to ſuffer this exceſs of rain more eaſily to evaporate. In the climate of Upſal, where the fall of rain is 24 inches, the proportion of ſilex is only 56 per cwt. but that of calx is 30; and in the climate of Paris, which is ſtill drier, the proportion of ſilex

filex is only from 46 to 51, and that of calx 37,5 per cwt. and hence we may perceive the neceſſity of attending to the average quantity of rain to judge of the proper conſtitution of fertile lands on fixed principles. The quantity of rain differs much in different parts of the ſame kingdom; but in general in Ireland, I believe it to be between 24 and 28 inches on an average.

In the two laſt mixtures the proportions vary conſiderably: The firſt may ſerve as a model for the heavier ſoils, and the ſecond for the lighter. In theſe and the following experiments, the carbonic principle ſeems to have been extracted from the ſurrounding garden-mould with which the pots communicated, by means of their perforation at bottom.

Barren Mixtures.

FIRST.

Mr. Tillet, in his ſixth and eighth experiments, mixed three-eighths of potters clay with three-

three-eighths of parings of limeſtone and two-eights of *fine* ſand; the only difference between this mixture and that of the firſt experiment was, that in the firſt experiment *coarſe ſand* was uſed, and in this *fine*, yet the former was fruitful in the higheſt degree; but in this the grain proſpered indeed the firſt year, but ſickened in the ſecond, and failed in the third: the proportions have been already ſtated. Here we have a clear proof of the neceſſity of an open texture in ſoils, without which the beſt proportions are uſeleſs.

SECOND.

In his thirteenth experiment he employed a mixture of two-eighths potters clay, four-eighths coarſe ſand, and two-eighths marl. The corn grew well the firſt year, poorly the ſecond, and decayed the third. The compoſition of the marl is not mentioned; but ſuppoſing it to contain 70 per cwt. of calx, and 30 of clay, of which the one-half is argill, it would form one

one of the richeſt ſorts of marls. The centeſimal proportions of this mixture ſhould be,

Silex	-	50 + 14 = 64
Argill	-	11 + 8 = 19
Calx	-	- 17
		100

And in the troy pound, ſuppoſing the water, &c. to amount to 100 grains, the quantities will be,

Silex	-	3622
Argill	-	1075
Calx	-	962
		5659

The ſterility of this mixture ſeems to proceed from a defect of calcareous earth. If we ſuppoſe the marl poorer in that earth, the defect will be ſtill greater. The retentive powers of the different earths with reſpect to water, being expreſſed by the quantities which each can retain without ſuffering any to drop, as above

above ſaid, and the quantities retained by the mixed maſs of theſe earths being proportional to the reſpective quantities of each, it ſhould ſeem that in fertile ſoils, where the fall of rain is from 20 to 30 inches, this power ſhould not exceed 70, nor fall ſhort of 50 per cent. It were of great conſequence to ſettle this point with preciſion; but to do this would require more numerous experiments. To explain my meaning I ſhall give one example.

Of the retentive Power of the Fertile Soils, mentioned by Mr. Bergman.

This ſoil contains, as we have already ſeen,

Silex	-	56
Argill	-	14
Calx	-	30

Now the retentive power of 100 parts

Silex	=	25
Argill	=	250
Calx	=	50

Conſequently the retentive power of

56 parts	Silex	=	13	
14 -	Argill	=	35	
30 -	Calx	=	15	
				63

The conſtitution of the Iriſh fertile ſoils has not been aſcertained, nor has the average annual quantity of rain been determined here. Indeed the ſolution of the queſtion propoſed by the Academy, does not ſtrictly require it ſhould, not having been limited to any particular country: but I ſhould ſuppoſe its beſt ſoil to approach to the nature of that of Upſal, the fall of rain being probably between 24 and 28 inches. In 1792, which was reckoned remarkably wet, it was 30½ inches in Dublin.

Before I quit the experiments of Mr. Tillet, it will be proper to mention a few made by him, which ſeem to invalidate the neceſſity of the preſence of the three ſimple earths in fertile ſoils.

1^mo. In his 26th experiment he tells us he employed only pure ſand, ſuch as is uſed for making glaſs, yet corn grew well in it the firſt year, indifferently the ſecond, and nearly failed in the third. Mr. Haſſenfraz having repeated the experiment in pots unperforated, did not find it to ſucceed even the firſt year, therefore the ſucceſs of Mr. Tillet was owing to the perforation at the bottom of his pot, through which water,

water, impregnated with the different earths, and coal muſt have paſſed. In fact, Mr. Tillet's concluſion is contradicted by univerſal experience.

2°. In his 28th experiment, in which powdered limeſtone only was employed, the corn ſown proſpered exceedingly during the three years. To the cauſe mentioned, in treating of the 26th, I muſt add, that the limeſtone he uſed was that of St. Leu, which contains clay, and conſequently ſilex and argill; it is ſo porous as to admit from 3-19ths to 1-5th of its weight of water, as Mr. Briſſon has ſhewn; and thus is eaſily decompoſed. The coarſe powder to which it was reduced anſwered the ſame purpoſe as coarſe ſilex; and the finer might nouriſh the plants.

3°. In his 30th experiment he employed mere potters clay; the grain grew tolerably well the firſt year, but periſhed the ſecond; on the third it flouriſhed moſt. It is hard to draw any ſpecific concluſion from this experiment, for it is plain that if the texture were not much looſer than that of clay, the corn could not grow at all, as was the caſe in his 6th and 8th expe-

riments, already mentioned, and as Mr. Haſſenfraz, who repeated this experiment, obſerved. Rain-water might however ſupply a ſmall quantity of calx ſufficient for a ſmall produce of corn.

I paſs over his experiments on old mortar, as the three earths were evidently contained in it, though in unknown proportions.

Soils on the declivity of hills, ought to be more retentive of water than thoſe on plains, as is evident.

CHAP III.

TO DETERMINE THE COMPOSITION OF A SOIL.

1mo. IN dry weather, when the ſoil is not over moiſt nor dry, let a ſurface of 16 ſquare inches be cut through to the depth of 8 inches; this may be effected by a right angled ſpade, formed for this particular purpoſe. Of the parallelopiped

parallelopiped thus dug up, the two inches next the ſurface ſhould be cut off to get rid of the graſs, and the greater part of the roots; we ſhall then have a ſolid 6 inches long, and 16 ſquare at the end = 96 cubic inches. Let this be weighed *; its weight will ſerve to find the ſpecific gravity of the ſoil; for if 96 cubic inches weigh n pounds, 1728 (a cubic foot) ſhould weigh x pounds, and x divided by 75,954 will expreſs by the quotient the ſpecific gravity of the ſoil. To render this and the ſubſequent operations more intelligible, I ſhould illuſtrate each by an example: Suppoſe the 96 cubic inches to weigh 6,66 pounds, then 1728 cubic inches ſhould weigh 120 lb. and $\frac{120}{75,954} = 1,579$.

2°. The earth being weighed, is next to be broken down and freed from all ſtony ſubſtances above the ſize of a pippin, and the remainder well mixed together, to render the whole as homogenous as poſſible; then weigh the ſtones

* Troy weights are generally more exactly made than avoirdupois, and therefore ſhould be preferred. A cubic foot of pure water, weighs 75,945 troy, very nearly, or 62,5 avoirdupois pounds, at the temperature 62°.

that were picked out, and find the proportion belonging to each pound of the reſiduary earth; call this the *ſtony ſupplement*, and denote it by *S*. Thus if the ſtones weigh 1 lb.=12 oz. the remainder, or mere earth, muſt weigh 5,66 lb. and if to 5,66lb. there belong 12 ozs. of ſtone, to 1 lb. muſt belong 2,12014 ozs. or 2 ozs. 57,66 grains = 1017,66 grs. This then is the ſtony ſupplement of each ſucceeding pound = *S*.

3°. Of the earth thus freed from ſtony matter, take 1 lb.—*S*. (that is the above caſe 1 lb. —2 oz. 57 two-thirds grs.) heat it nearly to redneſs in a flat veſſel, often ſtirring it for half an hour, and weigh it again when cold. Its loſs of weight will indicate the quantity of water contained in 1 lb of the ſoil. Note this loſs, and call it the *watery ſupplement* = *W*. Suppoſe it in this caſe 100 grains.

4°. Take another pound of the above maſs freed from ſtones, deducting the ſtony and watery ſupplements; that is 1 lb.—S—W, or in the above caſe 1 lb.—2 ozs. $57\frac{2}{3}$ grs. for ſtone, and—100 grains for water; conſequently 1 lb.—2 ozs. $157\frac{2}{3}$ grs. reduce it to powder:

boil

boil it in four times its weight of diſtilled water for half an hour; when cool, pour it off, firſt into a coarſe linen filtre to catch the fibrous particles of roots, and then through paper, to catch the finer clayey particles diffuſed through it: ſet by the clear water, add what remains on the filtre to the boiled maſs: if it be inſipid, as I ſuppoſe it to be, then weigh the fibrous matter, and call it the *fibrous ſupplement* = F. Suppoſe it in the example in hand to weigh 10 grs.

5°. Take two other pounds of the maſs freed from ſtony matter, No. II. ſubtracting from them the weight of the ſtony, watery, and fibrous ſubſtances already found; that is, 2lb. —2 S—2 W—2 F; pour twice their weight of warm diſtilled water on them, and let them ſtand twenty-four hours or longer; that is, until the water has acquired a colour, then pour it off and add more water as long as it changes colour; afterwards filtre the coloured water and evaporate it to a pint, or half a pint; ſet it in a cool place for three days, then take out the ſaline matter, if any be found, and ſet it by.

6°. Examine the liquor out of which the ſalts have been taken; if it does not effervesce with the marine acid, evaporate it to dryneſs, and weigh the reſiduum; if it does effervesce with acids, ſaturate it with the vitriolic or marine, and evaporate it to one fourth of the whole; when cool, take out the ſaline reſiduum, evaporate the remainder to dryneſs, and weigh it: this gives the coaly matter, which may be tried by projecting it on melted nitre, with which it will deflagrate. The half of this coaly matter call the *coaly ſupplement* of 1 lb. I ſhall ſuppoſe it to amount to 12 grs. and denote it by C.

7°. The filtred water, No. IV. is next to be gently evaporated to nearly one pint, and then ſuffered to reſt for three days in a cool place, that it may depoſit its ſaline contents, if it contains any; and theſe being taken out, the remainder muſt be evaporated nearly to dryneſs, and its ſaline and other contents examined. How this ſhould be done, I ſhall not mention, the methods being too various, tedious, and of too little conſequence; few ſalts occur except gypſum, which is eaſily diſtinguiſhed.

The

The water may be examined as to its ſaline contents when it is evaporated to a pint; if any ſalts be found, call them the *ſaline ſupplement*, and denote them by *S'*. I ſhall ſuppoſe them here = 4 grains.

8°. We now return to the boiled earthy reſiduum, No. IV. which we ſhall ſuppoſe fully freed from its ſaline matter, as, if it be not, it may eaſily be rendered ſo, by adding more hot water: let it then be dried as in No. III. is mentioned. Of this earthy matter thus dried, weigh off one ounce, deducting one-twelfth part of each of the ſupplements *S. W. F. C.* and *S'*; that is, in this caſe

$$\frac{1017,66}{12} = 84,405 + \frac{100}{12} = 8,333 + \frac{10}{12} =$$

$$8,333 + \frac{12}{12} = 1 + \frac{4}{12} = 0,3333 = 95 \text{ grs. in all}$$

—then 480—95=385 grains will remain, and repreſent the mere earthy matter in an ounce of the ſoil.

9°. Let this remainder be gradually thrown into a Florence flaſk, holding one and an half as much ſpirit of nitre as the earth weighs, and

alſo

alſo diluted with its own weight of water (the acids employed ſhould be freed from all contamination of the vitriolic acid;) the next day the flaſk with its contents being again weighed, the difference between the weights of the ingredients and the weights now found, will expreſs the quantity of air that eſcaped during the ſolution. Thus in the above caſe, the earth weighing 385 grains, the acid 577,5 grs. and the water 577,5 grs. in all 1540 grains, the weight after ſolution ſhould alſo be 1540, if nothing eſcaped; but if the ſoil contains calcareous matter, a loſs will always be found after ſolution. Let us ſuppoſe it to amount to 60 grains.

The weight of air that eſcaped, furniſhes us with one method of eſtimating the quantity of calcareous matter contained in the earth eſſayed; for mild calx generally contains 40 per cent. of air; then if 40 parts air indicate 100 of calcareous matter, 60 parts air will indicate 150 *.

10°. The ſolution is then to be carefully

* I take no account of magneſia, as in agriculture I believe it of little importance.

poured

poured off, and the undiſſolved maſs waſhed and ſhaken in diſtilled water; the whole thrown on a filtre, and ſweetened as long as the water that paſſes through has any taſte. The contents of this water ſhould be precipitated by a ſolution of mild mineral alkali: this precipitate alſo being waſhed and dried in a heat below redneſs, ſhould then be weighed. Thus we have another method of finding the weight of the calcareous matter.

11°. The undiſſolved maſs is next to be dried in the heat already mentioned, and the difference between its weight and the weight of the whole earthy maſs before ſolution ſhould be noted, as it furniſhes a third method of diſcovering the weight of the calcareous matter of which it is now deprived. Suppoſing this to amount to 150 grains, the weight of the undiſſolved reſiduum ſhould in the above caſe be 383—150=235 grains.

12°. Reduce the dried maſs into the fineſt powder, throw it into a Florence flaſk or glaſs retort, and pour on it three times its weight of pure oil of vitriol, digeſt in a ſtrong ſand heat, and at laſt raiſe the heat ſo as to make the

the acid boil; afterwards let it evaporate nearly to dryneſs: when cold, pour on it gradually ſix or eight times its weight of diſtilled water, and, after ſome hours, pour off the ſolution on a filtre; the filtre ſhould previouſly be weighed, and its edges ſoaked in melted tallow *; the ſubſtance found on the filtre being weighed (ſubtracting the weight of the filtre) gives the quantity of ſilicious matter; and this weight ſubſtracted from that of the dried maſs, gives that of the argill. In this caſe I will ſuppoſe the ſilicious maſs to weigh 140 grains, then the argillaceous ſhould weigh 95 grains.

Then the compoſition of one pound of the ſoil is as follows:

Stony matter	-	1017,66
Water	-	100
Fibres of roots	-	10
Soluble coal	-	12
Saline matter	-	4
Silex	140 × 12 =	1680
Argill	95 × 12 =	1140
Mild calx	150 × 12 =	1800
		5763,66 †

* An ingenious contrivance of Dr. Black.

† An error of 3,66 grains for decimals omitted in ſubtractions.

And

	Stony matter	18
	Fine ſilicious	29
		47
And in centeſimal proportion	Argill	22
	Mild calx	31
		100

Its retentive power is 82,25: hence I ſhould judge it to be unfertile in this climate, unleſs ſituated on a declivity, with an unimpeded fall. It may be called a *clayey loam.*

Mr. Young diſcovered a remarkable circumſtance attendant on fertile ſoils: he found that equal weights of different ſoils, being dried and reduced to powder, afforded quantities of air by diſtillation ſomewhat correſponding to the ratios of their values. This air was a mixture of fixed and inflammable airs, both proceeding, moſt probably, from the decompoſition of water by the coaly matter in the ſoil. The diſtillation ſhould be made from a retort glazed on the outſide. He found an ounce of dry ſoil, value five ſhillings, produced ten ounce meaſures;

Of value of from 5 to 12s. produced 28 oz.

	12 — 20	42
above	20	66

This appears to be a good method of eſtimating the proportion of coaly matter in ſoils that are in full heart; that is, not exhauſted, and freed from roots, &c. Another mark of the goodneſs of a ſoil is the length of the roots of wheat growing in it; for theſe are an inverſe proportion to each other, as, if the land be poor, the wheat will extend its roots to a great diſtance in queſt of food; whereas, if it be rich, they will not extend above five or ſix inches; but of theſe and ſome other empyrical marks, I ſhall ſay no more, as they do not tell us the defects of the ſoils.

CHAP.

CHAP. IV.

OF THE MANURES MOST ADVANTAGEOUSLY APPLICABLE TO THE DIFFERENT SOILS, AND OF THE CAUSES OF THEIR BENEFICIAL EFFECT IN EACH INSTANCE.

THE ſolution of the firſt part of this problem can only be derived from general practice of the moſt ſkilful farmers, corrected however and improved by the more preciſe determinations and reſtrictions of theory. That of the ſecond, I ſhall endeavour to deduce ſolely from the theory eſtabliſhed in the two laſt chapters. The whole is grounded on this ſimple propoſition—That *manures are applied to ſupply either the defective ingredients of a ſoil, or improve its texture, or correct its vices.*

I now proceed to conſider each ſoil in particular.

Of Clayey Soils.

The beſt manure for clayey ſoils is marl: in this

this all the books of agriculture are unanimous *; and of the different ſorts of marl, that which is moſt calcareous is beſt; the filicious next beſt; limeſtone-gravel beſt of all; and argillaceous marl leaſt advantageous †.

Clayey ſoils are defective both in conſtitution and in texture; they want the calcareous ingredient and coarſe ſand. Calcareous marl ſupplies the calcareous ingredient chiefly: limeſtone-gravel both. The other marls ſupply them in a leſſer degree. If the clay be analyzed, and its proportion of ſand and argill known, the ſpecies of marl moſt advantageouſly applicable may be determined ſtill better. For inſtance, if the argill notably exceeds or even amounts to the proportion of 40 or 50 per cwt. calcareous marl or limeſtone-gravel are the beſt improving manures, as they contain moſt of the calcareous ingredient; but if the ſilicious ingredient amounts to 75 or 80 per cwt. as it ſometimes does, argillaceous marl is moſt ſuitable.

* 4th Young's Eaſtern Tour, 404. 1ſt Body of Agriculture, 104, 108.
† Ibid, 108.

A mix-

A mixture of marl and dung is ſtill more advantageous *, becauſe the dung ſupplies the carbonaceous ingredient. But the marl muſt be uſed in the ſame quantity as if dung had not been applied, otherwiſe the operation muſt be more frequently repeated. How the quantity of marl or other manure can be eſtimated, I ſhall preſently ſhew.

If marl cannot be had, a mixture of coarſe ſand and lime perfectly effete or extinguiſhed, or chalk, will anſwer the ſame purpoſe, as it will ſupply the defective ingredient, and open the texture of the clay; ſo alſo ſand alone, or chalk, or powdered limeſtone, may anſwer, though leſs advantageouſly. Lime alone appears to me leſs proper, as it is apt to cake, and does not ſufficiently open the ſoil.

Where theſe manures cannot be had, coal aſhes, chips of wood, burned clay, brick-duſt, gravel, or even pebbles, are uſeful †; for all theſe improve the texture, and the former ſupply alſo the carbonaceous ingredient.

* 4th Young's Eaſtern Tour, 404.

† 5 Bergman, 107; and Young's Iriſh Tour, 249, 129, 136.

Before I advance farther, to prevent superfluous repetition, I ſhall lay down a ſecond general maxim; which is, That *dung is a proper ingredient in the appropriated manures of all ſorts of ſoils*, as it ſupplies the carbonaceous principle.

Of Clayey Loam.

This ſoil is defective either in the calcareous ingredient, or in the ſandy, or in both: if in the firſt, the proper manure is chalk *; if in the ſecond, ſand; if in both, ſilicious marl or limeſtone gravel, or effete lime and ſand.

The quantity of chalk that ſhould be employed, conſidered abſtractedly, ſhould be directly proportional to the defect of calcareous matter; but as ſuch a quantity cannot be added without diminiſhing the proportion of one of the other ingredients, a much ſmaller quantity muſt be employed, or elſe a ſubſtance which may convey ſome proportion of the other ingredient. The ſame obſervation holds

* 1ſt Young's Eaſtern Tour, 395.

alſo

alſo with reſpect to ſand. Thus we have ſeen, in the laſt chapter, a clayey loam, in which the ſandy ingredient was defective, and the argillaceous ſuperabundant, but the calcareous exact. Its compoſition ſtood thus:

Sand and Gravel -	47
Argill - - -	22
Mild calx - -	31

Here the ſandy part wants 10 per cwt. the argill is ſuperabundant; but we cannot increaſe the proportion of ſand without diminiſhing that of calx. Hence we muſt either uſe a ſmaller proportion of the ſandy ingredient than its defect requires, or apply a ſubſtance that would ſupply ſome proportion of the calcareous ingredient alſo: ſuch are limeſtone-gravel, ſilicious marl, effete lime, mixed with ſand or pounded limeſtone. Suppoſe the proportion of the ſubſtance to be employed were ſix per cwt.; that is, ſix pound for every hundred pounds of the ſoil, then the quantity requiſite for an acre may be calculated thus: a ſquare foot of this ſoil, cut down to the depth of fourteen inches, and paring off the two uppermoſt, as conſiſting chiefly of roots, &c. weighs, as

we have ſeen, 120 lb.; and if 100lb. requires ſix of the manure, 120 lb. will require 7,2; therefore every ſquare foot of the ſoil will require 7,2 of the manure: now an Engliſh acre contains 43560 ſquare feet; and conſequently 43560 multiplied into 7,2 of the manure = 313632 lb. or 208 cart loads, reckoning 1500lb. to the cart-load.

Chalky Soil.

This ſoil wants both the argillaceous and the ſtony, ſandy, or gravelly ingredients; therefore the beſt manure for it is clayey loam, or ſandy loam *; but when the chalk is ſo hard, as it frequently is in England, and ſo difficultly reducible to impalpable powder as to keep of itſelf the ſoil ſufficiently open, then clay is the beſt manure †, as in ſuch caſes the coarſe ſand or gravelly ingredients of loams are of no uſe. Some think, it is true, that pebbles in a field ſerve to preſerve or communicate heat.

* 5 Bergman, 107. † Young's Eaſtern Tour.

This

This uſe, however, is not ſufficiently aſcertained.

Chalky Loam.

The beſt manure for this ſoil is clay, or argillaceous marl *, if clay cannot be had; becauſe this ſoil is defective principally in the argillaceous ingredient. In Ireland, chalky ſoils or loams ſeldom occur, but light limeſtone ſoils frequently, and theſe do not differ eſſentially from chalky loams poor in argill: clay, therefore, and often the ſoil of bogs, ſhould ſerve as a manure for them.

Sandy Soils.

The beſt manure for theſe is calcareous marl †, which exactly correſponds with our theory; for theſe ſoils want both argillaceous and the calcareous ingredients; and this marl ſupplies both: the next beſt is argillaceous marl; and next to theſe, clay, mixed with lime,

* 4th Young's Eaſtern Tour, 404.
† 4th Young's Eaſtern Tour, 401, 412.

or calcareous or clayey loams. In Norfolk, they ſeem to value clay more than marl, probably becauſe their ſandy ſoils already contain calcareous parts; poſſibly alſo they miſname marl, calling mere chalk by that name. Lime or chalk are leſs proper, as they do not give ſufficient coherence to the ſoil; however, when mixed with earth or dung, they anſwer well *, becauſe they form a ſort of marl or compound, comprehending the defective ingredients.

Sandy Loams.

Theſe are defective chiefly in the calcareous ingredient, and in ſome degree alſo in the argillaceous; their texture too is imperfect, as they abound both in fine and coarſe ſand; chalk or lime would ſupply the firſt defect, but would leave the texture unamended. Hence they are uſed when better cannot be had †; yet calcareous or argillaceous marls are moſt proper ‡. Clay, after land has been chalked, anſwers, as

* Young's Eaſtern Tour, 397.
† 4th Young's Eaſtern Tour, 398.
‡ Ibid. 402.

we

we are told, remarkably well, becauſe it remedies the texture *.

Gravelly Loams.

Theſe ſoils are benefited by the application of marl, whether argillaceous or calcareous †, for reaſons which I ſuppoſe are now apparent: if the gravel be calcareous, clay may be employed ‡. A mixture of effete lime and clay ſhould anſwer in all caſes.

Till and Vitriolic Soils.

Theſe neceſſarily require the calcareous ingredient to neutralize their peccant acid: hence chalk, limeſtone-gravel, lime and calcareous marl, are moſt advantageouſly applied to them. *Home*, 35.

Bogs or Boggy Soils.

When theſe are well dried by ſufficient

* 4th Young's Annals, 413.
† 4th Young's Eaſtern Tour, 404, 406.
‡ 1ſt Eaſtern Tour.

drains,

drains, the nature of their ſoil ſhould be explored by analyſis, and an appropriate manure applied. In general, they ſhould firſt be burned, if capable of that operation, then gravelled. If their upper parts contain a ſufficiency of the carbonaceous principle, as often happens, they need not be burned. Limeſtone-gravel will anſwer beſt, or lime mixed with coarſe ſand or gravel, becauſe in general they are of a clayey nature; if more ſandy, lime may anſwer well, or calcareous marl. The preference in theſe caſes muſt be decided by analyſis *.

Heathy Soils.

Theſe ſhould firſt be burned, to deſtroy the heath and increaſe the carbonaceous principle: they ſhould then be analyzed, and the defective principles ſupplied. Lime is ſaid to deſtroy heath, and ſo is limeſtone gravel †: this is fitteſt when the ſoil is clayey; lime when it is gravelly ‡. Gypſum alſo anſwers remarkably well when the ſoils are dry.

* Young's Iriſh Tour, 233, 223.
† 4th Young's Eaſtern Tour, 396.
‡ Iriſh Tour, 212.

Of

Of ſome particular Manures.

We have now ſtated moſt of the known ſoils, and mentioned the manures which tend moſt to their improvement: there are, however, ſome others whoſe mode of action is not generally underſtood, and whoſe nature it will therefore be proper to explain.

Of Paring and Burning.

This mode of improvement is not particular to any ſpecies of ſoil, though poor ſoils that have few vegetables growing in them, will certainly profit leaſt by it.

Its advantages are,

Firſt, That it converts vegetables and their roots into coal. Hence it is that agricultural writers tell us, though without knowing the reaſon, that all violence of fire is to be avoided, and that a ſlow ſmothering fire is beſt*.

Secondly, That it deſtroys the old ſickly

* 1ſt Body of Agriculture, 210, 211.

roots,

roots, and thus leaves room for others younger and more vigorous.

Many have imagined that it diminiſhes and conſumes the ſoil; but repeated experience has ſhewn the contrary. I need only mention that of Colonel St. Leger, in Yorkſhire, related by Mr. Young in the 1ſt volume of his Eaſtern Tour, p. 182. It is well known that clays and loams are rather hardened than conſumed by heat. However, unleſs freſh ſeeds be committed, the ſoil will be unproductive for a number of years; the coaly principle may alſo be exhauſted by too many crops.

Of Gypſum.

This manure was diſcovered by Mr. Mayer, a German clergyman of uncommon merit, in the year 1768: it has ſince been applied with ſignal ſucceſs in Germany, Switzerland, France, and America. If in England it has not been ſo much approved of, it muſt be becauſe the calcareous principle prevails there almoſt univerſally: clayey lands are moſt improved by it. The time for ſpreading it is February or March,

and

and then it is to be thinly ſtrewed on the land at the rate of about eight buſhels to the acre: more would be hurtful. The *rationale* of its effects may be deduced from its extraordinary ſceptic power, for it is found to accelerate putrefaction in a higher degree than any other ſubſtance*; and hence it is not ploughed in like other manures, but barely ſtrewed on the ſurface of the land; and in the month of February, to convert the old graſs quickly into coal, to nouriſh the young growth.

2dly. From its being itſelf no inconſiderable part of the food of many plants, particularly of clover, pulſe, and corn, but the land on which it is ſtrewed muſt be dry, ſuch as would naturally ſuit clover, &c. otherwiſe it would be uſeleſs.

Thus far I have endeavoured to illuſtrate the important ſubject propoſed by the Academy, collecting and reflecting upon it the ſcattered rays reſulting from the lateſt chemical reſearches. The intimate connexion between many of theſe, ſeemingly the moſt abſtract

* Hiſtoire de la Putrefaction, 36.

and

and remote, with the hidden proceſſes of nature, may now be clearly perceived. Theſe grand and complicated operations, like a well fortified town, cannot be maſtered by ſtorm or a coup-de-main; the approaches muſt be made at a diſtance, and almoſt unſeen. Hence we may infer how little can be expected from agricultural ſocieties that do not unite chemiſtry and meteorology with their principal object.

With reſpect to the queſtion at preſent before us, the great deſiderata ſeem to be, *How to render charcoal ſoluble in water for the purpoſes of vegetation:* and *to diſcover that compoſition of the different earths beſt ſuited to detain or exhale the due proportion of the average quantity of moiſture that falls in each particular country.* On this relation, or adaptation, we have ſeen that the fertility of each eſſentially depends: we muſt alſo have perceived, that to a regular and ſyſtematic improvement of ſoils, a knowledge of their defects, and of the *quantum* of their defects, is abſolutely neceſſary. This information can be conveyed only by a chemical analyſis. Country farmers (at leaſt as long as the preſent abſurd mode of education

tion prevails) cannot be expected to poſſeſ ſufficient ſkill to execute the neceſſary proceſſes: but country apothecaries certainly may. The profit ariſing from ſuch experiments (ſhould the public encourage them) would ſufficiently excite them to acquire a branch of knowledge ſo nearly allied with their profeſſion. In the mean time, ſoils might be ſent to ſome ſkilful perſons in the capital by country gentlemen; who would thus be enabled to aſcertain and appreciate the advantages attending ſuch reſearches, and enlighten and encourage their more ignorant and diffident neighbours. Many of them might perhaps themſelves feel a taſte for occupations of this nature: occupations which not only fully ſuffice to fill up the many vacant hours and days which the ſolitude of a country life muſt frequently leave them, but are moreover ſweetened by the pleaſing recollection that of all others they tend moſt directly to the general happineſs of mankind.

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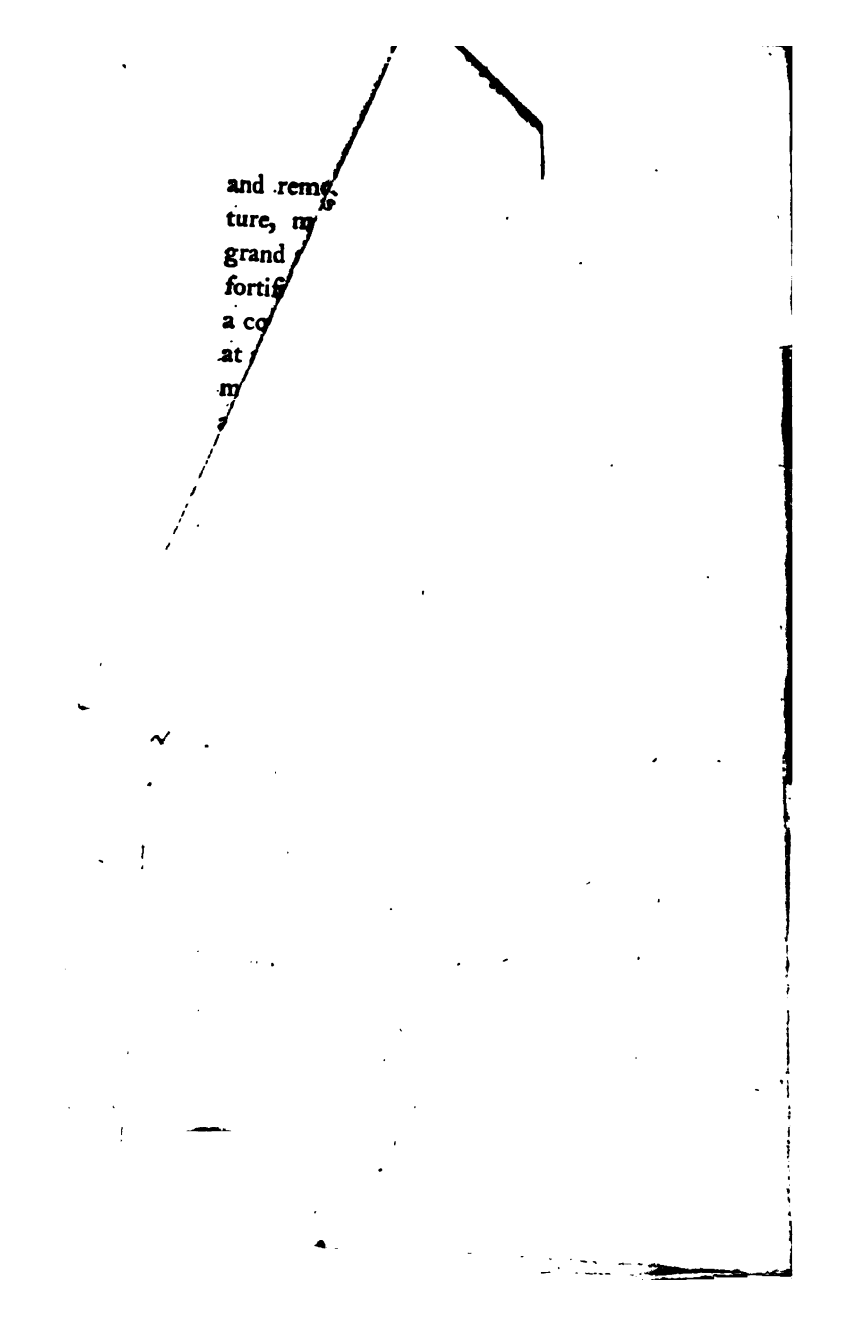

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